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## COLOR CURVE CONTROL CIRCUIT AND METHOD

### CLAIM OF PRIORITY

This application makes reference to, incorporates the same herein, and claims all benefits accruing under 35 U.S.C. §119 from an application entitled *Color Curve Control Circuit And Method* earlier filed in the Korean Industrial Property Office on Jun. 11, 1996, and there duly assigned Serial No. 20847/1996 by that Office.

### BACKGROUND OF THE INVENTION

#### 1. Field of the Invention

The present invention relates to a color curve control circuit and method. Specifically, this invention easily adjusts the colors as desired by the user, on the screen of a monitor using color gain and cutoff signals corresponding to the color temperature.

#### 2. Discussion of Related Art

Red does not indicate just one color. There are many variant colors from a red similar to orange to purplish red. There are also variant colors such as yellowish white and bluish white in white resulting from mixing red (R), green (G), and blue (B). Therefore, it is necessary to define the desirable three primary colors of light, R, G, and B, and standard white. The standard colors are employed by Commission International de L'Eclairage (CIE), and represented with R, G, B, and white points of light.

CIE defines the three primary colors according to wavelengths, thus light of 700 nm is defined as R, the light of 546 nm is defined as G, and the light of 435 nm is defined as B. CIE uses color matching where mix ratios of the three primary colors are calculated using a color matching measurement device to obtain various colors, thus colors are created by mixing the three colors according to calculated ratios.

Since human eyes sense colors differently and individually, and since they are most sensitive to the light near 550 nm, there are large perceived differences between R, G, B when the intensities of the three primary colors are represented by the absolute lumen or watt values. In color matching, a standard white is defined as the amount of R, G, and B which is necessary to match the standard white, and the amount of white, that is  $R+G+B$ , is set to 1. The amounts of R, G, and B is represented with a ratio to the white. For example, a color of 600 nm is made by mixing 0.34 of R, which is necessary to make the standard white, with 0.07 of G, which is also necessary to make the standard white. Such a mixing method is called a tristimulus value. An example is given below to demonstrate a conventional color mix method using this tristimulus value.

People react differently to colors. The same color can be perceived differently by different people. Therefore, colors are very important to a user who uses a monitor while working.

For example, when G and B are reduced from the value of a 9300° K white, the R value becomes relatively large and reddish colors are displayed. The user can utilize different standard white value in the manner that he/she stores different standard white values in memory and selects from them. For this, monitor manufacturers provide several limited colors, or values, which are most frequently utilized by the users. High quality monitors are designed so that the users can adjust the colors, but inaccurate color values are utilized because they must select them depending on their own eyes.

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The values supplied to users are abstract virtual color values, not the color values which appear actual color characteristics. When some software applications requiring more precise colors need a white value for the monitor, the users can only utilize the colors which are set during manufacture because they cannot know the white value of the monitor. Therefore, it is difficult for the users to adjust colors to particular values, and it takes much time. It is also a problem that the users cannot utilize a color adjustment function even though the monitor has this function.

### SUMMARY OF THE INVENTION

Accordingly, the present invention is directed to a color curve control circuit and method that substantially obviates one or more of the limitations and disadvantages of the related art.

An object of the present invention is to improve a color function which enables users to adjust colors to the state they want in a monitor, by adjusting colors displayed on a monitor using the R, G, and B gain and cutoff signals which change according to the color curve in color space.

To achieve these and other advantages, and in accordance with the purpose of the present invention as embodied and broadly described, a color curve control circuit utilizes a data input unit, for entering values to adjust colors on the screen of a monitor, a microcomputer, for processing color signals corresponding to color temperature using stored color temperature data according to a color curve control program in order to change the colors on the screen according to signals generated by the data input unit, and for generating color gain signals and color cutoff signals, and a digital to analog converter for converting the digital color gain and cutoff signals from the microcomputer into analog signals.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory and are intended to provide further explanation of the invention as claimed. Additional features and advantages of the invention will be set forth in the description which follows, and in part will be apparent from the description, or may be learned by practice of the invention. The objectives and other advantages of the invention will be realized and attained by the structure as illustrated in the written description and claims hereof, as well as the appended drawings.

### BRIEF DESCRIPTION OF THE ATTACHED DRAWINGS

The accompanying drawings, which are included to provide a further understanding of the invention and are incorporated in and constitute a part of this specification, illustrate embodiments of the invention that together with the description serve to explain the principles of the invention. In the drawings:

FIG. 1 is a circuit diagram of a color curve control circuit according to the principles of the present invention;

FIG. 2 is a graph showing a color curve corresponding to temperature; and

FIG. 3 is a flow chart for controlling the color curve according to the principles of the present invention.

### DETAILED DESCRIPTION OF PREFERRED EMBODIMENT

Reference will now be made in detail to the preferred embodiments of the present invention, examples of which are illustrated in the accompanying drawings.

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As shown in FIG. 1, a data input unit 10 includes a temperature sensing unit 11 for generating a temperature signal corresponding to the ambient temperature of the monitor, and a keypad 12 through which users selects an automatic mode or manual mode of operation and inputs color temperature values during the manual mode of operation. A microcomputer 20 receives the ambient temperature generated by temperature sensing unit 11 or the color temperature signals generated by keypad 12, converts the temperature signal into a digital signal, and processes data corresponding to the temperature signals using stored color temperature data and a color curve control program. A digital-to-analog converter (D/A converter) 30 receives digital R, G and B video gain and cutoff signals corresponding to the temperature signals from microcomputer 20, and converts the digital signals into analog signals. An on screen display (OSD) unit 40 processes OSD data which is serially transmitted from microcomputer 20, to display R, G and B OSD signals on the screen for the users. A video pre-amplifying unit 50 amplifies R, G and B video signals generated by a computer graphic adaptor (not shown) according to the levels of the R, G and B gain signals transmitted by D/A converter 30. A multiplexer 60 selects either the R, G and B video signals from video pre-amplifier 50 or the R, G and B OSD signals from OSD unit 40 in response to an enable signal OSD\_EN. A video main-amplifying unit 70 amplifies the R, G and B video signal or the R, G and B OSD signals, transmitted by multiplexer 60, according to the R, G and B cutoff levels generated by D/A converter 30. A cathode-ray tube (CRT) 80 produces beams in response to the amplified R, G and B signals output by video main-amplifying unit 70, through R, G and B cathodes to display the signals.

The operation of the above circuit is now described. The ambient temperature of the monitor is sensed by the temperature sensor of temperature sensing unit 11 in data input unit 10. Since an ambient temperature signal generated by temperature sensing unit 11 is weak, it is amplified by an operational amplifier OP1 and then transmitted to microcomputer 20. Additionally, color temperature signals, selected by a user using keypad 12 of data input unit 10 during a manual mode, are input to microcomputer 20.

Microcomputer 20 generates color gain signals corresponding to the amplified ambient temperature or selected color temperature signals transmitted by temperature sensing unit 11 and keypad 12, respectively. The process by which microcomputer 20 generates the color gain signals is as follows.

The temperature signals generated by temperature sensing unit 11 are analog signals. When a user selects an automatic mode of operation using keypad 12, microcomputer 20 receives these analog temperature signals and converts them into digital signals. When a user selects a manual mode of operation using keypad 12, the user selects a color temperature using keypad 12, and keypad 12 generates a color temperature signal corresponding to the selected color temperature, and transmits it to microcomputer 20. Microcomputer 20 generates the R, G and B gain and cutoff signals, according to the selected operation mode, corresponding to the ambient temperature signal or color temperature signal using a color curve control program to read from stored color temperature data.

Microcomputer 20, which generates R, G and B gain and cutoff signals corresponding to the ambient temperature signal or color temperature signal, confirms information on colors to be illustrated on a screen as a result of processing the R, G and B gain and cutoff signals. Microcomputer 20

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also generates OSD values, which includes information on the color temperature signal selected by the user or the ambient temperature sensed by temperature sensing unit 11, for transmission to OSD unit 40 to be displayed and viewed by the user. The R, G and B gain and cutoff signals generated by microcomputer 20 are transmitted to D/A converter 40 through a serial connection.

The R, G and B gain and cutoff signals generated by microcomputer 20 are digital signals. These digital R, G and B gain and cutoff signals are converted into analog signals by D/A converter 30, then transmitted to video pre-amplifying unit 50 and video main-amplifying unit 70, respectively.

OSD unit 40 receives the OSD data for displaying characters representing the sensed ambient temperature by temperature sensing unit 11 or the color temperature selected by a user through keypad 12. OSD unit 40 also receives horizontal and vertical sync signals transmitted through a computer graphic adaptor (not shown). The data which is input to OSD unit 40, is generated as signals R\_OSD, G\_OSD, B\_OSD, and OSD\_EN in synchronization with the horizontal and vertical sync signals from the graphic adaptor. The signals generated by OSD unit 40 are transmitted to multiplexer 60. This operation of displaying the information and color signals from microcomputer 20 on the screen of the monitor, is described below.

The R, G and B gain signals (R\_Gain, G\_Gain, B\_Gain) generated by microcomputer 20 are converted into analog signals by D/A converter 30. The analog R, G and B gain signals (R\_Gain, G\_Gain, B\_Gain) and R, G and B video signals from the computer graphic adaptor are transmitted to video pre-amplifying unit 50. R video and R gain signals are supplied to operational amplifier OP2, G video and G gain signals are supplied to operational amplifier OP3, and B video and B gain signals are supplied to the operational amplifier OP4.

The R, G and B video signals, which are supplied to each operational amplifier of video pre-amplifying unit 50, are amplified to the levels of the R, G and B gain signals. The R, G and B video signals, amplified by video pre-amplifying unit 50, are transmitted to multiplexer 60. Multiplexer 60 receives signals OSD\_R, OSD\_G, OSD\_B, and OSD\_EN from OSD unit 40 with the pre-amplified R, G and B video signals. R video signal and signal OSD\_R are supplied to operational amplifier OP5, G video signal and signal OSD\_G are supplied to operational amplifier OP6, and B video signal and signal OSD\_B are supplied to operational amplifier OP7.

The R, G and B video signals or the OSD signals, R\_OSD, G\_OSD, and B\_OSD, of operational amplifiers OP5-OP7 are transmitted to video main-amplifying unit 70 in response to signal OSD\_EN. At this time, only when multiplexer 60 is turned ON by OSD\_EN, are the OSD signals, OSD\_R, OSD\_G, and OSD\_B, transmitted from the operational amplifiers of multiplexer 60 to video main-amplifying unit 70. The OSD\_EN signal is generated only when the automatic or manual color correction modes are selected by the user using keypad 12, at all other times the R, G and B video signals output from the computer graphic adaptor is displayed according to the current R, G and B gain and cutoff signals applied to amplifiers 50 and 70, respectively.

Video main-amplifying unit 70 receives the R, G and B video or OSD signals selected according to the signal OSD\_EN, and R, G and B cutoff signals generated by D/A converter 30. R video or R\_OSD, and R\_Cutoff signals are

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supplied to operational amplifier OP8, G video or G\_OSD, and G\_Cutoff signals are supplied to operational amplifier OP9, and B video or B\_OSD, and B\_Cutoff signals are supplied to operational amplifier OP10 in video main-amplifying unit 70. The R, G and B video or OSD signals, which are transmitted to operational amplifiers OP8-OP10 of video main-amplifying unit 70, are amplified according to the levels of the color cutoff signals (R\_Cutoff, G\_Cutoff, B\_Cutoff), transmitted by D/A converter 30. The amplified signals are sent to corresponding cathodes R (R.K), G (G.K) and B (B.K) for display on the screen of the monitor through CRT 80.

A general color theory about displaying colors the users want using ambient temperature signals or selected color temperature signals is described below with reference to the attached drawings.

FIG. 2 is a graph illustrating a color curve according to temperature. The arrows centered around the origin O represent R, G and B. The oval around the origin O represents the area of white. The curved line between points b and r represents color temperature in Kelvin, herein the temperature of point b is 9300° K, and the temperature of point r is 5000° K. The following is a detailed description of this graph.

A way of displaying colors in a monitor is explained through a color reduction method using R, G and B. It is widely known that maximum R, G and B create a white. The range of colors recognized by human beings as being white is wide. The Kelvin color temperature scale is utilized to standardize colors in this wide color range. As the color temperature increases, colors become close to blue (point b), whereas colors approach red (point r) as the temperature decreases. Therefore, color signals corresponding to temperature can be controlled by changing the R, G and B mix ratio.

A color adjustment method using a color curve is explained with reference to the attached drawings.

As shown in FIG. 3, a range of temperatures (T\_LEN) is established according to T\_MIN and T\_MAX in factory mode during manufacture (step S91). When the range of temperatures, T\_LEN, is established, R, G and B gain and cutoff values corresponding to the respective T\_MIN and T\_MAX are produced (step S92). The R, G and B gain and cutoff data corresponding to the range of temperature, T\_LEN, is stored (step S93). A user selects a color correction mode as one of an automatic mode and a manual mode (step S94). The sensed ambient temperature is detected by microprocessor 20 to be compared to the stored values (step S95), when the automatic mode is selected in step S94. A color temperature value is entered by a user to be compared to the stored values (step S96) when the manual mode is selected in step S94. R, G and B gain and cutoff values corresponding to the temperature range, T\_LEN, are read (step S97) following steps S95 or S96.

The more detailed description of this procedure is set forth in the following.

When establishing the temperature range, T\_LEN, in the factory mode during manufacture, the temperature range is defined with minimum and maximum Kelvin temperatures. When the minimum and maximum temperatures are established in the factory mode, their coordinates are calculated (step S91). At step S92, R, G and B gain and cutoff values corresponding to the minimum and maximum temperatures, T\_MIN and T\_MAX, are calculated. For example, when the minimum temperature T\_MIN is set at 5000° K, coordinates corresponding to 5000° K are calculated. When the

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maximum temperature T\_MAX is set at 9300° K, coordinates corresponding to 9300° K are calculated. R, G and B gain and cutoff values corresponding to the temperature range between minimum and maximum temperatures T\_MIN and T\_MAX, is generated using these coordinates. Additionally, a color curve value S, which effects the properties of the curve, is a value fixed during manufacture according to CRT properties. When the calculated R, G and B gain and cutoff data corresponding to the temperature range between minimum and maximum temperatures, T\_MIN and T\_MAX, are stored at step S93, the operation in a factory mode is completed. When the calculated values are stored at step S93, a temperature is entered according to either a sensed ambient temperature or by the user at steps S95 and S96, respectively, as discussed above following selection of either an automatic or manual mode of color correction in step S94. Then, the R, G and B gain and cutoff values corresponding to the temperature range, T\_LEN, are read (step S97) following steps S95 or S96.

Coordinates xc corresponding to the input temperature are calculated (step S98) from the following formula using the color curve value S:

$$xc = T - (T - T\_len)(x + T\_len) \times S$$

wherein, T is a predetermined temperature, x is a temperature which is substituted for medium temperature, T\_LEN is a range of temperature, and S is the slope of the temperature curve.

When the coordinates of xc corresponding to the predetermined temperature are obtained, color temperature data Rx, Gx, and Bx, corresponding to the predetermined temperature are calculated. The data is obtained using the following formulas:

$$Rx = (Rmin \times (T\_MAX - xc) + Rmax \times (xc - T\_MIN)) / (T\_MAX - T\_MIN)$$

$$Gx = (Gmin \times (T\_MAX - xc) + Gmax \times (xc - T\_MIN)) / (T\_MAX - T\_MIN)$$

$$Bx = (Bmin \times (T\_MAX - xc) + Bmax \times (xc - T\_MIN)) / (T\_MAX - T\_MIN)$$

wherein, the calculated color temperature data, Rx, Gx, and Bx, are digital signals. The color temperature data (Rx, Gx, and Bx) is converted onto R, G and B gain and cutoff data. That is, video signal gains and cutoff values (R\_Gain, G\_Gain, B\_Gain, R\_Cutoff, G\_Cutoff and B\_Cutoff) are calculated from the values, T\_MIN and T\_MAX, according to the temperature which is input to microprocessor 20 in steps S95 or S96. The gain and cutoff values are obtained (step 99) using the following formulas:

$$R\_Gain = (Rmin \times (T\_MAX - xc) + Rmax \times (xc - T\_MIN)) / (T\_MAX - T\_MIN)$$

$$G\_Gain = (Gmin \times (T\_MAX - xc) + Gmax \times (xc - T\_MIN)) / (T\_MAX - T\_MIN)$$

$$B\_Gain = (Bmin \times (T\_MAX - xc) + Bmax \times (xc - T\_MIN)) / (T\_MAX - T\_MIN)$$

$$R\_Cutoff = (Rmin \times (T\_MAX - xc) + Rmax \times (xc - T\_MIN)) / (T\_MAX - T\_MIN)$$

$$G\_Cutoff = (Gmin \times (T\_MAX - xc) + Gmax \times (xc - T\_MIN)) / (T\_MAX - T\_MIN)$$

$$B\_Cutoff = (Bmin \times (T\_MAX - xc) + Bmax \times (xc - T\_MIN)) / (T\_MAX - T\_MIN)$$

The digital gain and cutoff values are converted into analog signals at step S100.